ELECTRIC RADIANT HOUSE HEATING

U. S. DEPARTMENT OF AGRICULTURE

RURAL ELECTRIFICATION ADMINISTRATION

Revised December 1950

ELECTRIC RADIANT HOUSE HEATING

By
Technical Standards Division.
U.S. Rural Electrification Administration.
United States Department of Agriculture
Washington, D. C.

Electric heating equipment may be classified into two main classes as radiant or convection, or a combination of the two. To understand the characteristics of radiant heating equipment it is necessary to be familiar with the physical laws governing the transfer of heat.

Transfer of Heat

Heat may be transferred in the following methods:

1. Conduction
2. Radiation
3. Convection

Heat may travel by either one, two, or three of the methods simultaneously or consecutively. Heat is conducted by means of molecular vibration; radiated by means of electro-magnetic waves and convected by the flow of currents in fluids (water and air).

Conduction

Conduction is the transfer of heat between two bodies or parts of a body in direct contact with each other. This may be illustrated by heating one end of a metal rod and having the heat travel progressively to the other end of the rod. The heat is transferred by direct contact of one molecule to another within the material. Conduction occurs in solids, to some extent in liquids, and to almost negligible extent in air and other gases.

Radiation

Radiation is the transmission of heat through a medium which occupies all intermolecular spaces. Radiant heat travels in straight lines until intercepted or absorbed by some body or object. It obeys the same laws as light; therefore, for all practical purposes, the transmission of pure radiant heat may be considered instantaneous. Radiant heat will pass through certain solid substances, such as glass, without heating them and is reflected by various other materials. Radiant heat will pass through dry gases, regardless of their temperature, without heating them to any appreciable extent; however, air containing water vapor or dust will intercept and absorb radiant heat. Thus the earth's atmosphere receives a part of its heat by radiation from the sun by virtue of the water vapor and dust in the air. Pure air will not intercept or absorb radiant heat.

All bodies above absolute zero temperature radiate heat. For a body to become warm it must absorb more radiant heat than it is emitting. When heat energy leaves the surface of the heat source, it is converted into long wave length rays. As soon as the rays strike a solid object, they are immediately converted back into heat energy and the effect of warmth is experienced by the receiving body. A good example of the effect of radiant heat is the difference of noticeable warmth of a person while standing in the sun or under the shade of a tree on a cold sunshiny day even though the temperature is the same in both areas. When standing under the tree the person feels colder than when in the path of the radiant heat from the sun.

Convection

Convection is the transfer of heat by the actual flow movement of the medium heated. This type of heat may be illustrated by the conventional house heating system where the air around a heated radiator becomes warm, expands, and rises to be replaced by cold air. This sets up a circulation within the room. The circulation may also be produced by mechanical means. Convected heat becomes effective when the circulating air comes into direct contact with a cooler body and transmits heat by conduction to that body. In the case of a warmer body it is effective when it limits the dissipation of heat from that body.

Functions of a Heating System in a House

The primary source of heat for human beings is the heat generated inside the body.. The human body is a heat-generating unit adjusted so as to maintain a blood temperature of approximately 100 F. as long as the physical functions of the body are normal. Therefore, the function of a mechanical heating system in the home is not to heat the body but to keep the material environment in such condition that the heat of the body will not be dissipated too fast for human vitality and well-being.

Heat energy is always transferred from points of higher temperature to those of lower temperature. Since this is true, the heating system warms the house and air, but it does not warm the body, since the temperature of the walls and air is only around 70 F. while the surface temperature of the body is approximately 85 F. Because of this difference in temperatures, the transfer of heat is out of the body and not inward. The house heating system is used to maintain the environment at a point so that a comfortable and stable body temperature can be maintained without the production of extra heat by the body which would cause discomfort.

Types of Electric Radiant Heating Systems for Homes

The various types of electric radiant heating systems known to be manufactured are:

1. Conductive rubber panels
2. Heating cable either insulated or uninsulated
3. Small resistance wire incorporated in a thin dielectric fabric or embedded in a "sandwich" panel
4. Tempered glass which has an alloy conductor fused into one side

The major types of electric radiant heating equipment, presently available, and a brief description of their construction and operation follow.

Conductive Rubber Panel

USKON, manufactured by U. S. Rubber Company, is a natural rubber to which has been added special materials permitting the conduction of electricity. There are no electrical wires within the panel other than the two aluminum foil potential leads to the conductive rubber layers. The rubber itself conducts electricity and provides the radiant heat.

The conductive rubber layer is sealed between layers of phenolic, impregnated, insulation. The laminated construction is made rigid by a backing of 3/16 in asbestos board. The panels are approximately 1/4 in. thick. USKON comes in standard sizes of 3 x 4 ft, 4 x 4 ft, 4 x 8 ft and also special sizes. The panels operate on 220 volts a-c, and are made of two standard wattage ratings; namely, 17 watts per square foot and 22 watts per square foot. The 17 watt per square foot panels are used in rooms with normal heating requirements and the 22 watt panels in bath rooms, over large window areas, and in rooms with abnormally high heat losses. Each room should be controlled and heated separately.

The manufacturer claims the panels will not exceed 100 F. with outside temperatures as low as 0 F, and for a panel operating continually, the surface temperature will not exceed 120 F. under any outside weather conditions.

USKON heating panels are connected in groups on parallel circuits. The total current carried by any one circuit should not exceed 20 amperes. The number of panels in any house or room depends upon the heat loss that has to be replaced to maintain the desired temperature.

USKON heating panels are installed in the ceiling. In new construction the panels are nailed directly to the ceiling joist after the framework of the house is completed. A representative of the manufacturer should be contacted for information in installation of the panels.

The most desirable arrangement for USKON panels is a peripheral pattern with the center part of the ceiling being filled in with any standard building board. In small rooms of limited ceiling area, the panels are centered within the room. The entire ceiling of a room is not covered with panels except in extremely small rooms or in rooms with very high heat losses. The peripheral pattern is advantageous in that it provides a greater degree of direct radiant heat and it provides slight air circulation which is desirable from a comfort standpoint.

USKON panels are controlled by a standard low voltage air actuated or bimetal thermostat.

The price of the panel is approximately $1.65 per square foot for the 17 watt panel and $1.75 per square foot for the 22 watt panel. This does not include the installation cost or the cost of the necessary control equipment.

USKON panels are not approved by Underwriter's Laboratories at the present time, and their design and structure present some installation and decorative problems.

Heating Cable

The "Heatsum" cable, manufactured by L. N. Roberson Company, may be installed in the ceiling, over existing ceilings, in wall plaster, and in concrete slabs or floors.

The "Heatsum" cable is approximately 1/8 in. in diameter, and has a plastic insulation. The "Heatsum" cable is laid in a sinuous arrangement; that is, it is laid as a flat coil with a definite spacing between turns. The spacing between turns depends on the heat loss from the room to be heated and the area of the surface to which the cable is to be applied. To determine the length of cable required to heat a room, the heat loss or heat load has to be calculated. This load is translated from Btu to watts. The correct length of cable is determined by the load in watts, and the cable installation is arranged so as to provide equal spacing to the applied surface.

Heating cable is available in a variety of sizes from 17 ft. 47 watt units for use on 120 volts, a-c to 1020 ft., 2810 watt units for use on 240 volts, a-c. The company states that the cable is so designed that the maximum temperature on the cable insulation when hung in air at 50 F. is approximately 112 F.

The "Heatsum" cable price varies with the length and wattage of the cable. A 17 ft., 47 watt cable costs about $4.25. A 1020 ft., 2810 watt cable costs approximately $53.80. The overall cost of this type of heating depends upon the amount of cable required, the thermostats and miscellaneous items, and the labor for installation. The adaptability of this type of heating equipment to old construction may prove uneconomical in most cases.

Electric Baseboard Heaters

The Wesix Electric Baseboard heater is designed to be placed around the room at the location normally occupied by the wooden baseboard. The electric baseboards are constructed in sections from 2 ft. 8 in. to 4 ft. in length. The units are rated by the manufacturer at 100 watts per linear foot and operate on 220 volts, a-c.

Each section of baseboard contains two adjacent heating coils extending between terminal blocks at each end. It is equipped with knockouts on the end plates for connecting additional sections, and knockouts in the back for incoming service connections. As many sections of baseboards may be connected together in parallel as desired, within the safe limits of the electric circuit. Connections from the control equipment are made by running parallel circuits using the raceway area provided at the toe of the electric baseboard heater for the wiring.

There are two types of control sections provided for the baseboard heaters. One type includes a thermostat together with a double pole switch. This section is 8 in. long and is designed to match the baseboard in appearance. The other type includes only a thermostat and is designed to be used with a double pole switch that is mounted on the wall. Either type of control may be used up to a maximum capacity of 4000 watts. The baseboard sections may also be controlled by a wall type thermostat.

The retail price of the baseboard heater ranges from approximately $16 for the 2 ft. 8 in. section to $34 for the 4 ft. section. The control section costs approximately $16. The number of sections required to heat a room depends on the heat loss and the size of sections used in the installation.

Radiant Glass Heating Panels

Radiant glass heating panels are manufactured by Continental Radiant Glass Heating Corporation, and by Appleman Glass Works. These companies' products are very similar in appearance, construction, and operation. For this reason, only Continental Radiant Glass Heaters will be discussed.

The radiant glass heating panel consists of three parts:

1. The heating element is a plate of tempered glass 16 x 24 in., approximately 1/4 in. thick, into which is fused a continuous aluminum alloy grid.

2. The glass plate is mounted in an aluminum reflector plate with an air space between it and the glass.

3. This unit is mounted in a steel frame with overall dimensions of 21 x 31 in.

The Radiant Glass Heaters, models EH1B, EH1BB, EH4B, EH3B, EH3BB, and EH5B, offered by the Continental Radiant Heating Corporation bears the label of, and are listed by the Underwriters' Laboratories, Incorporated.

Electric current passing through the aluminum grid of the Continental Radiant Glass Heaters raises the temperature of the grid and glass panel to approximately 340 F.

The aluminum reflector is placed between the glass panel and the back of the mounting frame. When the glass panel is above room air temperature, air from the room enters a horizontal opening beneath the glass panel. It passes vertically through the space between the glass panel and the aluminum reflector and through the space between the aluminum reflector and the mounting frame. The air is thus heated and is discharged to the room through a horizontal opening at the top of the heater. The movement of air through the two passages and the reflective property of the aluminum reflector provides sufficient cooling to allow the radiant glass heater to be installed directly against combustible construction.

Room air also moves over the front of the glass panel by natural convection and is raised in temperature. The heating accomplished by the radiant glass heaters is a combination of convection and radiant heating since the glass panel, when at higher temperature than other surfaces in the room, also acts as a radiating surface.

The internal wiring of the radiant glass heaters is installed by the manufacturer and a junction box is provided on the back of the mounting frame for connection to the wiring circuit.

The radiant glass heaters are rated at 1000 watts on 115/230 volts, a-c. This rating is on the basis of the stabilized current input after an operating period of approximately 20 to 25 minutes. The panels when first placed in operation will have an initial power demand of approximately 140 percent of the steady demand on continuous duty. The wattage decreases as the temperature of the panel increases until the panel reaches its normal temperature of approximately 340 F. Because of the high initial demand it is very important to consider the proper wire size and over-load protective devices for the circuits supplying the electric energy to the radiant heaters.

The maximum number of radiant glass heaters which may be operated on one thermostat on a-c current depends upon the make and type of relay and also the service voltage provided. Four radiant glass panels is the maximum number that should be controlled by one thermostat.

Each room, or heated space, or pair of spaces not separated by doors should be heated independently of all others. The radiant panels should be installed on external walls and under windows if possible. Radiant glass heaters should never be installed in the floor or ceiling. The upper edge of the mounting frame should not be more than three feet from the floor of the room.

The Continental Radiant Glass Heaters cost approximately $50.00. This price does not include controls, house wiring or installation.

Two of the conditions of acceptance listed by the Federal Housing Administration for their insuring offices are:

1. "Evidence shall be submitted that adequate electrical service will be provided by the electric utility company."

2. "The labeled voltage of the radiant glass heaters shall be within 5 percent plus or minus of the service voltage which will be provided by the electrical utility company for heating."

These are two of the requirements of Federal Housing Administration that have to be met before an FHA loan can be obtained by the home buyers, and may be of primary importance to some of the REA-financed systems.

Costs of Heating With Different Fuels

To give a comparison of heating costs with different fuels, the following assumptions were made:

1. Btu loss per hour from the dwelling was assumed as 50,000.
2. The degree days were taken as 4,000.
3. Design temperature outside the home was taken as zero degrees F.
4. Design temperature inside the home was taken as 70 degrees F.
5. The various costs of fuels were assumed.

The computations were made according to procedures given in the Federal Housing Administration Bulletins, Heating Bulletin, MPR-Reference, paragraph 501-A January 25, 1949 and Mechanical Engineering Bulletin No. ME-5, Special Heating Systems, August 1, 1949.

The following tables set forth the approximate cost of heating with different fuels:

Coal
(Anthracite or High Grade Bituminous)

Method of Heating	Estimated Annual Fuel Consumption (tons)	Assumed Cost of Fuel per Ton (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Stoker fired	3.66	$16.00	$58.56
2. Hand fired	4.39	16.00	70.24
Space heater			
Hand fired	5.49	16.00	87.84

Coal
(Low Grade Bituminous)

Method of Heating	Estimated Annual Fuel Consumption (tons)	Assumed Cost of Fuel per Ton (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Stoker fired	4.76	$14.00	$66.64
2. Hand fired	5.72	14.00	80.08
Space heater			
Hand fired	7.14	14.00	99.96

Fuel Oil
(No. 1 and No. 2)

Method of Heating	Estimated Annual Fuel Consumption (gallons)	Assumed Cost of Fuel per Gallon (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Oil fired unit	572	$0.10	$57.20
	572	0.12	68.64
	572	0.14	80.08
2. Conversion burner	602	0.10	60.20
	602	0.12	72.24
	602	0.14	84.28
Space heater or floor furnace	635	0.10	63.50
	635	0.12	76.20
	635	0.14	88.90

Gas
(100,000 Btu per Therm)

Method of Heating	Estimated Annual Fuel Consumption (therms)	Assumed Cost of Fuel per Therm (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Gas fired unit	762	$0.08	$60.96
	762	0.10	76.20
	762	0.12	91.44
2. Conversion burner	878	0.08	70.24
	878	0.10	87.80
	878	0.12	105.36
Space heater, wall heater or floor furnace	878	0.08	70.24
	878	0.10	87.80
	878	0.12	105.36

Electricity

Method of Heating	Estimated Annual Kwh Consumption (kwh)	Assumed Cost per Kwh (dollars)	Estimated Annual Energy Cost (dollars)
Electric Panel Heaters	14,286	$0.005	71.43
	14,286	0.01	142.86
	14,286	0.015	214.29

The comparative costs of various methods of heating with different fuels in any area may be estimated by substituting the prevailing costs of fuels in that locality in the assumed cost per unit column and multiplying it by the estimated annual fuel consumption. The amount of fuel of any type required annually to heat any particular building will necessarily be governed by the heat loss which is dependent upon the construction of the building, degree days, design temperature, wind velocity and other factors.

General Comments on Radiant Heating

In designing an electric heating system, it must be remembered that one kwh of electricity can supply a maximum of 3413 Btu per hour of heat.

Electric radiant heat is 100 percent efficient, therefore 3413 Btu can be used in the calculations.

The Btu loss has to be calculated before any figures can be given on the kwh required to heat any house and maintain the desired temperature. The heat loss through the walls, windows, floors, doors, roof, etc., is the amount that has to be supplied by the electric heating system to maintain the desired temperature in the home. Consideration has to be given to these and the type of construction before recommendations can be made as to the type and number of electric heaters necessary for heating a building having a given number of cubic feet.

Various construction materials and combinations of these will allow heat to be lost from a house at different rates. Insulation and other means of reducing heat losses will contribute to greater living comfort and will also lower the costs of heating. It is strongly recommended that heat losses be restricted or reduced by all possible methods within practicability to obtain the highest efficiency justified by the saving and comfort produced.

Insulation should be placed in the ceiling regardless of the home location or the method used to heat the home. The savings in heating costs will usually pay for the original cost of the insulation within a few years and help to maintain a more even temperature throughout the house. Storm windows or double glass will reduce the heat lost through windows by approximately 50 percent. Where wall insulation can be installed during construction, the cost of insulation can usually be covered within a few years from reduction of heating costs. The cost of wall insulation in an old house may not be justified because the first cost cannot be covered during the life of the structure. The amount of insulation used has to be determined for each individual home on the basis of heat costs savings during the useful life of the structure.

Partial List of Manufacturers of Electric Radiant Heating Equipment

1. Appleman Glass Works
   Electriglas Radiant Heat Division
   Bergenfield, New Jersey

2. Continental Radiant Glass
   Heating Corporation
   1 East 35th Street
   New York, New York

3. L. N. Roberson Company
   1539 East 103rd Street
   Seattle 55, Washington

4. Thermador Electrical
   Manufacturing Company
   Los Angeles 22, California

5. United States Rubber Company
   1230 Avenue of the Americas
   New York, New York

6. Wesix Electric Heater Company
   390 First Street
   San Francisco 5, California